The Big Bounce Theory

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Abstract

Over the past few years, we have been hearing the term "**The Big Bounce Theory**", quite a lot. The Big Bounce Theory is a hypothetical scientific theory of the formation of the universe which boils down to the idea that the universe is caught in a cycle where it expands after the Big Bang, then begins to contract. As we know there are many models about the formation of the universe and we could write several articles about them, but in this article the Big Bounce is at the forefront of much discussion.
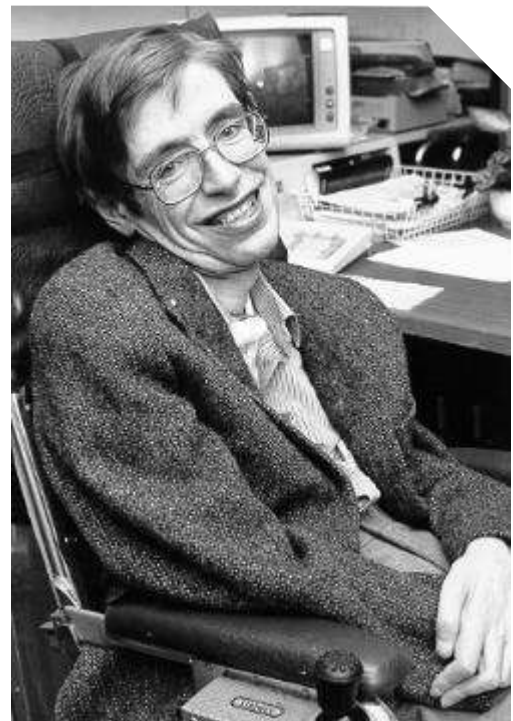
The world as we have created it is a process of our thinking. It cannot be changed without changing our thinking.

— Albert Einstein

There is a fundamental difference between religion, which is based on authority, and science, which is based on observation and reason. Science will win because it works.

— Stephen Hawking

The Story of the Universe

In **Big Bang model** (Cosmic model that presumes that the whole observable universe has expanded from an earlier state of much higher density) one finds that our universe started with an explosion − sending the matter and energy hurtling in all directions. This was not any ordinary explosion as might occur today, which would have a point of origin (center) and would spread out from that point. The explosion occurred simultaneously everywhere, filling all space with infinite heat and energy. At this time, order and structure were just beginning to emerge − the universe was hotter and denser than anything we can imagine (at such temperatures as high as this are reached in Hydrogen-bomb explosions and densities (of about a trillion trillion trillion trillion trillion trillion (1 with 72 zeros after it) tons per cubic inch) gravity and quantum mechanics were no longer treated as two separate entities as they were in point-particle quantum field theory, the four known forces were unified as one unified super force) and was very rapidly expanding much faster than the speed of light (this did not violate Einstein's dictum that nothing can travel faster than light, because it was empty space that was expanding) and cooling in a way consistent with Einstein field equations. Planck energy (

$$\sqrt{\frac{\hbar c^5}{G}}$$

) was the energy scale of the big bang, where all the forces were unified into a single

superforce. At Planck length ($\sqrt{\frac{\hbar G}{c^3}}$), the gravitational force was as strong as the other forces

and space-time was "**foamy**" − filled with tiny bubbles and wormholes appearing and disappearing into the vacuum. Quasars were quasi-stellar objects that were formed shortly after the big bang. As the universe was expanding, the temperature was decreasing. Since the temperature was decreasing, the universe was cooling and its curvature energy was converted into matter like a formless water vapor freezes into snowflakes whose unique patterns arise from a combination of symmetry and randomness. Approximately 10^{-37} seconds into the expansion, a phase transition caused a cosmic inflation, during which the universe underwent an incredible amount of superliminal expansion and grew exponentially by a factor e^{3Ht} (where H was a constant called Hubble parameter and t was the time) – just as the prices grew by a factor of ten million in a period of 18 months in Germany after the First World War and it doubled in size every tiny fraction of a second – just as prices double every year in certain countries. After inflation stopped, the universe was not in a de Sitter phase and its rate of

expansion was no longer proportional to its volume since H (which measures the rate of expansion of the universe, and its inverse correlates roughly to the age of the universe) was no longer constant. At that time, the entire universe had grown by an unimaginable factor of 10^{50} and consisted of a hot plasma "soup" of high energetic quarks as well as leptons (a group of particles which interacted with each other by exchanging new particles called the W and Z bosons as well as photons). The composition of the hot plasma was identical everywhere and quarks and gluons were "deconfined" and free to move over distances much larger than the hadron size (>>1 fm) in a soup called quark gluon plasma (QGP). There were a number of different varieties of quarks: there were six "flavors," which we now call up, down, strange, charmed, bottom, and top. And among the leptons the electron was a stable object and muon (that had mass 207 times larger than electron and now belongs to the second redundant generation of particles found in the Standard Model) and the tauon (that had mass 3,490 times the mass of the electron) were allowed to decay into other particles. And associated to each charged lepton, there were three distinct kinds of ghostly particles called neutrinos (the most mysterious of subatomic particles − which are affected only by the weak force and gravity, are difficult to detect because they rarely interact with other forms of matter. Although they can easily pass through a planet or solid walls, they seldom leave a trace of their existence. Evidence of neutrino oscillations prove that neutrinos are not massless but instead have a mass less than one- hundred-thousandth that of an electron):

- the electron neutrino (which was predicted in the early 1930s by Wolfgang Pauli and discovered by Frederick Reines and Clyde Cowan in mid-1950s)
- the muon neutrino (which was discovered by physicists when studying the cosmic rays in late 1930s)
- the tauon neutrino (a heavier cousin of the electron neutrino)

Temperatures were so high that these quarks and leptons were moving around so fast that they escaped any attraction toward each other due to nuclear or electromagnetic forces. However, they possessed so much energy that whenever they collided, particle – antiparticle pairs of all kinds were being continuously created and destroyed in collisions. And the uncertainty in the position of the particle times the uncertainty in its velocity times the mass of the particle was never smaller than a certain quantity, which was known as Planck's constant. Similarly, $\Delta E \times \Delta t$

was $\geq \dfrac{h}{4\pi}$ (where h was a quantity called Planck's constant and $\pi = 3.14159\ldots$ was the familiar ratio of the circumference of a circle to its diameter). Hence the Heisenberg's uncertainty principle (which captures the heart of quantum mechanics – i.e. features normally thought of as being so basic as to be beyond question (e.g. that objects have definite positions and speeds and that they have definite energies at definite moments) are now seen as mere artifacts of Planck's constant being so tiny on the scales of the everyday world) was a fundamental, inescapable property of the universe. At some point an unknown reaction led to a very small excess of quarks and leptons over antiquarks and antileptons — of the order of one part in 30 million. This resulted in the predominance of matter over antimatter in the universe. The universe continued to decrease in density and fall in temperature, hence the typical energy of each particle was decreased in inverse proportion to the size of the universe (since the average energy – or speed – of the particles was simply a measure of the temperature of the universe). The symmetry (a central part of the theory [and] its experimental confirmation would be a compelling, albeit circumstantial, piece of evidence for strings) however, was unstable and, as the universe cooled, a process called spontaneous symmetry breaking phase transitions placed the fundamental forces of physics and the parameters of elementary particles into their present form. After about 10^{-11} seconds, the picture becomes less speculative, since particle energies drop to values that can be attained in particle physics experiments. At about 10^{-6} seconds, there was a continuous exchange of smallest constituents of the strong force called gluons between the quarks and this resulted in a force that pulled the quarks to form little wisps of matter which obeys the strong interactions and makes up only a tiny fraction of the matter in the universe and is dwarfed by dark matter called the baryons (protons – a positively charged particles very similar to the neutrons, which accounts for roughly half the particles in the nucleus of most atoms − and neutrons – a neutral subatomic particles which, along with the protons, makes up the nuclei of atoms – belonged to the class baryons) as well as other particles. The small excess of quarks over antiquarks led to a small excess of baryons over antibaryons. The proton was composed of two up quarks and one down quark and the neutron was composed of two down quarks and one up quark. And other particles contained other quarks (strange, charmed, bottom, and top), but these all had a much greater mass and decayed very rapidly into protons and neutrons. The charge on the up quark was $= +\dfrac{2}{3}$ e and the chargeon the down quark was =

$-\dfrac{1}{3}$ e. The other quarks possessed charges of $+\dfrac{2}{3}$ e or $-\dfrac{1}{3}$ e. The charges of the quarks added up in the combination that composed the proton but cancelled out in the combination that composed the neutron i.e.

$$\text{Proton charge was} = (\dfrac{2}{3}\text{ e}) + (\dfrac{2}{3}\text{ e}) + (-\dfrac{1}{3}\text{ e}) = e$$

$$\text{Neutron charge was} = (\dfrac{2}{3}\text{ e}) + (-\dfrac{1}{3}\text{ e}) + (-\dfrac{1}{3}\text{ e}) = 0$$

And the force that confined the rest mass energy of the proton or the neutron to its radius was so strong that it is now proved very difficult if not impossible to obtain an isolated quark. As we try to pull them out of the proton or neutron it gets more and more difficult. Even stranger is the suggestion that the harder and harder if we could drag a quark out of a proton this force gets bigger and bigger − rather like the force in a spring as it is stretched causing the quark to snap back immediately to its original position. This **property of confinement** prevented one from observing an isolated quark (and the question of whether it makes sense to say quarks really exist if we can never isolate one was a controversial issue in the years after the quark model was first proposed). However, now it has been revealed that experiments with large particle accelerators indicate that at high energies the strong force becomes much weaker, and one can observe an isolated quark. In fact, the standard model (one of the most successful physical theories of all time and since it fails to account for gravity (and seems so ugly), theoretical physicists feel it cannot be the final theory) in its current form requires that the quarks not be free. The observation of a free quark would falsify that **aspect of the standard model**, although nicely confirm the quark idea itself and fits all the experimental data concerning particle physics without exception. Each quark felt the strong force and possessed baryon number $=\dfrac{1}{3}$: the total baryon number of the proton or the neutron was the sum of the baryon numbers of the quarks from which it was composed. And the electrons and neutrinos contained no quarks; they were themselves truly fundamental particles. And since there were no electrically charged particles lighter than an electron and a proton, the electrons and protons were prevented from decaying into lighter particles − such as photons (that carried zero mass, zero charge, a definite energy $E = pc$ and a momentum $p = mc$) and less massive neutrinos (with very little mass, no electric charge, and no radius − and, adding insult to injury, no strong force acted on it). And a

free neutron being heavier than the proton **was not prevented from decaying into a proton** (plus an electron and an antineutrino). The temperature was now no longer high enough to create new proton− antiproton pairs, so a mass annihilation immediately followed, leaving just one in 10^{10} of the original protons and neutrons, and none of their antiparticles (i.e., antiparticle was sort of the reverse of matter particle. The counterparts of electrons were positrons (positively charged), and the counterparts of protons were antiprotons (negatively charged). Even neutrons had an antiparticle: antineutrons. A similar process happened at about 1 second for electrons and positrons (positron: the antiparticle of an electron with exactly the same mass as an electron but its electric charge is +1e). After these annihilations, the remaining protons, neutrons and electrons were no longer moving **relativistically and the energy density of the universe was** dominated by photons − (what are sometimes referred to as the messenger particles for the electromagnetic force) − with a minor contribution from neutrinos. At $E=mc^2 \geq$ 100 GeV: the distinction between the electromagnetic force and the weak force disappeared. The density of the universe was about 4×10^9 times the density of water and much hotter than the center of even the hottest star – no ordinary components of matter as we know them – molecules, atoms, nuclei – could hold together at this temperature. And the total positive charge due to protons plus the total negative charge due to electrons in the universe was = 0 (Just what it was if electromagnetism would not dominate over gravity and for the universe to remain electrically neutral). As per Albert Einstein's theory of gravity: the four dimensional space-time curved, stretched, contracted and wiggled. Free neutron was highly unstable and decayed into: proton + electron + antineutrino. π^0 decayed into two photons: $\pi^0 \rightarrow \gamma + \gamma$. Intrinsic energy of π^0 was = total energy of photons. K^0 decayed into two charged pions: $K^0 \rightarrow \pi^+ + \pi^-$. Intrinsic energy of K^0 was = total energy of pions. And a few minutes into the expansion, when the temperature was about a billion (one thousand million; 10^9) Kelvin and the density was about that of air, protons and neutrons no longer had sufficient energy to escape the attraction of the strong nuclear force and they started to combine together to produce the universe's deuterium and helium nuclei in a process **called Big Bang nucleosynthesis**. And most of the protons remained uncombined as hydrogen nuclei. And inside the tiny core of an atom, consisting of protons and neutrons, which was roughly 10^{-13} cm across or roughly an angstrom, a proton was never permanently a proton and also a neutron was never permanently a neutron. They kept on changing into each other. A neutron emitted a π **meson** (a particle predicted by **Hideki Yukawa**

(for which he was awarded the Nobel Prize in physics in 1949) – composed of a quark and antiquark, which is unstable because the quark and antiquark can annihilate each other, producing electrons − Particles of negative electricity − and other particles) and became proton and a proton absorbed a π meson and became a neutron. That is, the exchange force resulted due to the absorption and emission of π mesons kept the protons and neutrons bound in the nucleus. And the time in which the absorption and emission of π mesons took place was so small that π mesons were not detected. And a property of the strong force called asymptotic freedom caused it to become weaker at short distances. Hence, although quarks were bound in nuclei by the strong force, they moved within nuclei almost as if they felt no force at all. Gamma rays of very short wavelength, was produced in radioactive decay (**spontaneous breakdown of one type of atomic nucleus into another**) or by collisions of elementary particles. If the crests and troughs of two waves coincided, they resulted in a stronger wave, but if one wave's crests coincided with another's troughs, the two waves cancelled each other. The electron orbits in atoms were such that the angular momentum of the electron about the nucleus was an integer of $\frac{h}{2\pi}$, where h denoted Planck's constant. And when an electron changed from one orbit to another one nearer to the atomic nucleus, energy (equivalent to the difference of energy between the two orbits) was released in the form of a photon of wavelength $= \dfrac{\text{Planck constant}}{\text{momentum}}$ — which collided with an another atom, it moved an electron from an orbit nearer the nucleus to one farther away. **Higgs field** permeated the universe: whose value determined masses of elementary particles, broke the symmetry among the fundamental forces, and fixed the energy of the vacuum. The speed of light was the same for all observers. But the measurements of space and time differed for observers who were moving with respect to one another. Antigravity was opposite of gravity, which was repulsive rather than attractive. This antigravity force, however, was much too small to be measured in the laboratory, so it had no practical implications.

Within only a few hours of the big bang, the Big Bang nucleosynthesis stopped. And after that, for the next million years or so, the universe just continued expanding, without anything much happening. Eventually, once the temperature had dropped to a few thousand degrees, there was a continuous exchange of virtual photons between the nuclei and the electrons. And the

exchange was good enough to produce —— what else? —— A force (proportional to a quantity called their charge and inversely proportional to the square of the distance between them). And that force pulled the electrons (elementary particles which exhibited both particle-like and wavelike characteristics, depending on the circumstances) towards the nuclei to form neutral atoms (the basic unit of ordinary matter, made up of a tiny nucleus (consisting of protons and neutrons) surrounded by orbiting electrons). And these atoms reflected, absorbed, and scattered light and the resulted light was red shifted by the expansion of the universe towards the microwave region of the electromagnetic spectrum. And there was cosmic microwave background radiation (which, through the last 15 billion years of cosmic expansion, has now cooled to a mere handful of degrees above absolute zero (–273ºC − the lowest possible temperature, at which substances contain no heat energy and all vibrations stop—almost: **the water molecules are as fixed in their equilibrium positions as quantum uncertainty allows**) and today, scientists measure tiny deviations within this background radiation to provide evidence for inflation or other theories). The effect of the cosmic expansion was to decrease the cosmic microwave background temperature. At redshift z, the CMB temperature was: $T = T_0 (1 + z)$, where $T_0 = 2.728 \pm 0.002$ K. At $z \geq 1000$: matter and radiation achieved thermal equilibrium. The photons (or any other classical waves) were emitted or absorbed only in discrete quanta, whose energy was proportional to their frequency, and inversely proportional to their wavelength.

$$E = h\upsilon = \frac{hc}{\lambda}$$

The wavelength of photons increased as it travelled across the universe. Electricity and magnetism were inseparable aspects of the electromagnetic waves (waves of oscillating electric and magnetic fields) and these waves traveled at a fixed speed that matched exactly the speed of light given by:

$$c = \frac{\text{magnitude of electric field}}{\text{magnitude of magnetic field}} = \frac{1}{\sqrt{\text{vacuum permittivity} \times \text{vacuum permeability}}}$$

Because relativistic mass $= \dfrac{\text{rest mass}}{\sqrt{1-\dfrac{v^2}{c^2}}}$: the faster an particle moved, the more kinetic energy it

possessed. But according to E= mc², kinetic energy added to an particle's mass, so the faster an particle moved, the harder it was to further increase the particle's speed. This effect was really significant only for particles moving at speeds close to the speed of light. As a particle approached the speed of light, its mass increased ever more quickly to infinite, so it took infinite amount of energy to speed it up further. This was the reason that any material particle was forever confined by relativity to move at speeds slower than the speed of light. Only photons that had no intrinsic mass moved at the speed of light.

$$E^2 = p^2c^2 + m_0^2c^4$$

$m_0 = 0$:

$$E = pc$$

Nuclear transition was mediated by the weak force, in which the nuclear charge ($Q = Ze$) changed by one, either:

$$Ze \rightarrow (Z+1) \, e \text{ with the emission of an electron plus an antineutrino;}$$

or $Ze \rightarrow (Z-1)$ e with the emission of a positron plus a neutrino. Electrons, neutrinos, protons, and neutrons obeyed the Pauli's exclusion principle; their wave function was antisymmetric under interchange of particle position. The curvature of four-dimensional spacetime emerged from the distribution of matter and the motion of matter was influenced by the curvature of spacetime. Described mathematically by:

$$G_{\mu\nu} = \frac{8\pi G}{c^2} \times T_{\mu\nu}$$

where $G_{\mu\nu}$ denoted the Einstein tensor, constructed from the Ricci tensor, and had dimensions of inverse length, and $T_{\mu\nu}$ was the four-dimensional stress-energy tensor and had dimensions of mass per unit volume.

The irregularities in the universe meant that some regions of the nearly uniformly distributed atoms had slightly higher density than others. The gravitational attraction of the extra density slowed the expansion of the region, and eventually caused the region to collapse to form galaxies and stars. And the nuclear reactions in the stars transformed hydrogen to helium

(composed of two protons and two neutrons and **symbolized by $_2\text{He}^4$**, highly stable—as predicted by the rules of quantum mechanics) to carbon (with their self- bonding properties, provide the immense variety for the complex cellular machinery— no other element offers a comparable range of possibilities) with the release of an enormous amount of energy via Einstein's equation $E = mc^2$. This was the energy that lighted up the stars. And the process continued converting the carbon to oxygen to silicon to iron. And the nuclear reaction ceased at iron. And the star experienced several chemical changes in its innermost core and these changes required huge amount of energy which was supplied by the severe gravitational contraction. And as a result the central region of the star collapsed to form a neutron star. And the outer region of the star (whose mass > 1.4 solar masses) got blown off in a tremendous explosion called a supernova, which outshone an entire galaxy of 100 billion stars, spraying the manufactured elements into space. And these elements provided some of the raw material for the generation of cloud of rotating gas which went to form the sun (which emitted approximately a black body radiation at a rate proportional to the **product of fourth power of its absolute temperature and its surface area**) and a small amount of the heavier elements collected together to form the asteroids, stars, comets, and the bodies that now orbit the sun as planets like the Earth and their presence caused the fabric of space around them to warp (more massive the bodies, the greater the distortion it caused in the surrounding space). Matter in galaxies, clusters, and possibly between clusters that did not scattered or absorbed light and was not been observed directly but was detected by its gravitational effect. As much as 90 percent of the mass of the universe was in the form of dark matter. A thin tube of space-time connected distant regions of the universe. Wormholes provided link to parallel or baby universes and also provided the possibility of time travel. The laws of quantum mechanics accurately governed the structure of atoms and molecules and the anthropic laws of nuclear and statistical physics governed the burning of stars – which made the universe appear to be simple and comprehensible. The conservation of matter and energy posited that the total amount of matter and energy in the universe was a constant. The infall of matter onto a forming star occurred because of their mutual gravitational attraction. **Accretion** was essential in the formation of stars and planetary systems. Active galactic nuclei were thought to be powered by the release of potential gravitational energy by accretion of matter onto a supermassive black hole. Two black holes orbiting each other (**like stars in a binary system**) radiated away significant orbital

energy by emission of gravitational radiation that lead to orbital decay − with the two black holes spiraling down toward each other and ultimately coalescing to form a single black hole. 1.4 solar masses was the maximum mass of cold matter that can be supported by degeneracy pressure, especially of electrons. This laid the maximum possible masses for white dwarfs and for the cores of massive stars before they collapse. **Turbulent fragmentation** took place in which a giant cloud of gas fragments broke into smaller clouds, which later became protostars. The volatile material of comets (**cosmic snowballs of frozen gases, rock and dust that, when passing close to the Sun, warms and begins to release gases**) was primarily amorphous water ice but also constituted, with some variation in quantity, other simple molecules including a few percent (relative to water) of carbon dioxide, carbon monoxide, formaldehyde, methanol, and methane. The inelastic scattering of high energy photons by charged electrons, where energy was lost by the photon because of the electron recoil. A photon carried momentum, part of which was exchanged between the photon and the electron. Conservation of energy and momentum yielded an increase in the photon wavelength (and hence a decrease in photon energy) as measured in the initial rest frame of the electron equal to:

$$\lambda - \lambda_0 = \lambda_C \,(1-\cos\theta)$$

where λ_0 denoted the wavelength of the incident photon, θ the scattering angle, λ the photon wavelength after scattering, and λ_C a constant equal to 2.43×10^{-12} m, called the Compton wavelength. If the scattered photon wavelength exceeded the Compton wavelength, then the energy exchange was irrelevant and the scattering was elastic (Thomson scattering). In plasma, collisions were mediated through long-range electrostatic (Coulomb) forces between electrons and protons. **Dark cloud** was a part of the interstellar medium that emitted little or no light at visible wavelengths and was composed of dust and gas that strongly absorbed the light of stars. Most of the gas was in molecular form and the densities were of the order of 10^3 to 10^4 particles cm^{-3} with masses of 10^2 to 10^4 solar masses and sizes of a few parsecs.

The earth was initially very hot and without an atmosphere. In the course of time the planet earth produced volcanoes and the volcanoes emitted water vapor, carbon dioxide and other gases. And there was an atmosphere. This early atmosphere contained no oxygen, but a lot of other gases and among them some were poisonous, such as hydrogen sulfide (the gas that gives

rotten eggs their smell). And the sunlight dissociated water vapor and there was oxygen. And carbon dioxide in excess heated the earth and balance was needed. So carbon dioxide dissolved to form carbonic acid and carbonic acid on rocks produced limestone and subducted limestone fed volcanoes that released more carbon dioxide. And there was high temperature and high temperature meant more evaporation and dissolved more carbon dioxide. And as the carbon dioxide turned into limestone, the temperature began to fall. And a consequence of this was that most of the water vapor condensed and formed the oceans. And the low temperature meant less evaporation and carbon dioxide began to build up in the atmosphere. And the cycle went on for billions of years. And after the few **billion years, volcanoes ceased to exist**. And the molten earth cooled, forming a hardened, outer crust. And the earth's atmosphere consisted of nitrogen, oxygen, carbon dioxide, plus other miscellaneous gases (hydrogen sulfide, methane, water vapor, and ammonia). And then a continuous electric current through the atmosphere simulated lightning storms. And some of the gases came to be arranged in the form of more complex organic molecules such as **simple amino acids (the basic chemical subunit of proteins, when, when linked together, formed proteins)** and carbohydrates (which were very simple sugars). And the water vapor in the atmosphere probably caused millions of seconds of torrential rains, during which the organic molecules reached the earth. And it took two and a half billion years for an ooze of organic molecules to react and built earliest cells as a result of chance combinations of atoms into large structures called macromolecules and then advance to a wide variety of one − celled organisms, and another billion years to evolve through a highly sophisticated form of life to primitive mammals endowed with two elements: genes (a set of instructions that tell them how to sustain and multiply themselves), and metabolism (a mechanism to carry out the instructions). But then evolution seemed to have speeded up. It only took about a hundred million years to develop from the early mammals (the highest class of animals, including the ordinary hairy quadrupeds, the whales and Mammoths, and characterized by the production of living young which are nourished after birth by milk from the teats (**MAMMAE, MAMMARY GLANDS**) of the mother) to Homosapiens. With the invention of sex, two organisms exchanged whole paragraphs, pages and books of their DNA helix, producing new varieties for the sieve of natural selection. And the natural selection was a choice of stable forms and a rejection of unstable ones. And the variation within a species occurred randomly, and that the survival or extinction of **each organism** depended upon its

ability to adapt to the environment. And organisms that found sex uninteresting quickly became extinct. Language acquisition took place in which something called curiosity ensued which triggered the breath of perception and our caveman ancestors became conscious of their existence and they learned to talk and they developed spoken language – **Glaciation** occurred in which a thousand-year ice age began. Innovation occurred in which advanced tools were widely made and used – religion transpired in which a diversity of beliefs emerged – animal domestication took place in which humans domesticated animals. Food surplus production succeeded in which humans developed and promoted agriculture – inscription took place in which writing was invented and it allowed the communication of ideas. Warring nations occurred in which nation battled nation for resources – empire creation and destruction took place in which the first empire in human history came and went – civilization emerged in which many and sundry events occurred and a constitution was written – industrialization took place in which automated manufacturing and agriculture revolutionized the world – World conflagrations took place in which most of the world was at war and humans developed nuclear weapons – Computerization evolved in which computers were developed. Space exploration emerged in which humans began to explore outer space – population explosion preceded in which the human population of the earth increased at a very rapid pace. Superpower confrontation took place in which two powerful nations risked it all – internet expansion occurred in which a network of computers developed. Resignations took place in which one human quitted his job – reunification took place in which a wall went up and then came down. World Wide Web creation emerged in which a new medium was created. Composition took place in which a book was written and future events were discussed. The thermal neutrons were captured by atmospheric nitrogen ^{14}N, a proton was emitted and the cosmogenic nuclide ^{14}C resulted. ^{14}C produced in the lower stratosphere was transported down to the troposphere and carried out to earth by rain, and its traces were assimilated by living matter and stored, for instance in trees. The escape velocity (speed giving a zero total energy [kinetic energy + gravitational potential energy]) from the gravitational pull of a star of mass M and radius R was:

$$v_{es} = \sqrt{\frac{2GM}{R}}$$

where: G denoted the Newtonian gravitational constant. Adding mass to the star (increasing

M), or compressing the star (reducing R) increased $v_{es} = \sqrt{\dfrac{2GM}{R}}$. When the escape velocity

exceeded the speed of light: the star became a black hole of radius $r = \dfrac{2GM}{c^2}$. Because $r = \dfrac{2GM}{c^2}$:
the speed of light was the ultimate velocity in the universe, this denoted that nothing can escape
a black hole, once an particle had crossed the event horizon. Black holes were of various sizes.
Galactic black holes, lurking in the center of vast cosmic islands of stars and quasars, weighed
millions to billions of solar masses. Stellar black holes were the remnant of a dying star,
perhaps originally up to forty times the mass of our Sun. In a dying star, the electron
degeneracy pressure was the repulsive force that prevented electrons or neutrons from
completely collapsing. And this force was due to the **Pauli Exclusion Principle**, which stated
that no two electrons can occupy precisely the same quantum state. The total entropy of the
universe was always increasing, which meant that the second law of thermodynamics
ultimately predicted the heat death of the universe. Entropy was conceptually associated with
disorder; the greater the entropy the less ordered energy was available. The farther a galaxy was
from Earth, the faster it moved. And this observation agreed with Albert Einstein's theory of an
expanding universe. The distance D between almost any pair of galaxies was increasing at a

rate: $v = \dfrac{dD}{dt} = HD$. Beyond a certain distance, known as the Hubble distance $\dfrac{c}{H}$, it exceeded the

velocity greater than the speed of light in vacuum. But, this was not a violation of relativity,
because recession velocity was caused not by motion through space but by the expansion of
space. A collapsed star consisted of a solid mass of neutrons was neutron star and these stars of
3 solar masses collapsed into a black hole. An object that experienced only gravitational forces
moved along a geodesic in a spacetime, and its acceleration was zero. Black holes radiated
away energy in form of Hawking radiation via quantum effects, in which case their horizon
contracted. Cosmic rays interacting with the Earth's atmosphere created neutrons (of mass
slightly greater than that of protons), as well as other particles and cosmogenic nuclides.
Because neutrons were electrically neutral, their motion was not influenced by the Earth's
geomagnetic field. Volcanoes were subjected to periodic eruptions during which molten rock
(magma) and volcanic ash flew to the Earth's surface.

The interaction between 2 objects in the universe depended only on their distances and masses:

$$F_G = \frac{GMm}{r^2}$$

where F_G denoted the attractive force, M and m the masses, r was their separation. **Hydrostatic equilibrium** was the condition in a star where the inward force of gravity was precisely balanced by the outward force due to the gradient of pressure. In the absence of hydrostatic equilibrium, a star expanded or contracted on the free-fall time scale. A slight imbalance led to stellar pulsation. A large imbalance led to either catastrophic collapse or violent explosion, or both. The known forces of the universe were divided into four classes:

- **Gravity:** This was the weakest of the four; it acted on everything in the universe as an attraction. And if not for this force, everything would have gone zinging off into outer space and the life sustaining star would have detonated like trillions upon trillions of hydrogen bombs.
- **Electromagnetism:** This was much stronger than gravity; it acted only on particles with an electric charge, being repulsive between charges of the same sign and attractive between charges of the opposite sign.
- **Weak nuclear force:** This caused radioactivity and played a vital role in the formation of the elements in stars.
- **Strong nuclear force:** This force held together the protons and neutrons inside the nucleus of an atom. And it was this same force that held together the quarks to form protons and neutrons.

If these forces were unified, the positively charged particles (**protons**) − which constituted up much of the mass of ordinary matter − would have been unstable, and eventually decayed into lighter particles such as antielectrons. However, the probability of a proton in the universe gaining sufficient energy to decay was so small that one has to wait at least a million million million million million years. When an electron and a positron approached each other, they annihilated i.e., destroyed each other. During the process their masses were converted into energy in accordance with $E = mc^2$. The energy thus released manifested as γ photons.

The massive bodies that were accelerated caused the emission of gravity waves, ripples in the curvature of 4 dimensional fabric of space-time that traveled away in all directions like waves in a lake at a specific speed, the speed of light. Like light, gravity waves carried energy away from the bodies that emit them. The ultimate fate of the universe was determined by a parameter called critical density $\frac{3H^2}{8\pi G}$:

- Density of the universe $> \frac{3H^2}{8\pi G}$ implied: the universe will eventually stop expanding then collapse.
- Density of the universe $< \frac{3H^2}{8\pi G}$ implied: the universe will expand forever.

Below Planck Time: $\sqrt{\frac{\hbar G}{c^5}}$

Below Planck Length: $\sqrt{\frac{\hbar G}{c^3}}$

Above Planck Temperature: $\sqrt{\frac{\hbar c^5}{G k_B^2}}$

All the known laws of physics were meaningless.

Weird things occurred at the atomic and subatomic level:
- Energy was quantized ($E = nh\upsilon$).
- Momentum was quantized ($L = n\hbar$).
- Charge was quantized ($Q = ne$).

4 **NUMBERS** described the characteristics of electrons and their orbitals:
- **Principal quantum number:** a number that described the average distance of the orbital from the nucleus and the energy of the electron in an atom.

- **Angular momentum quantum number:** a number that described the shape of the orbital.
- Magnetic quantum number: a number that described how the various orbitals were oriented in space.
- **Spin quantum number:** a number that described the direction the electron was spinning in a magnetic field — either clockwise or counterclockwise.

The stars were shining, supernovae were exploding, black holes were forming, winds on planetary surfaces were blowing dust around, and hot things like coffee mugs were cooling down and the cosmological arrow of time pointed in the direction of the universe's expansion. The space was simply the lowest energy state of the universe. It was neither empty nor uninteresting, and its energy was not necessarily zero. Because $E = mc^2$ (the equation that represents the correlation of energy to matter: essentially, energy and matter were but two different forms of the same thing) and due to the fuzziness of quantum theory (that implies: photon carries mass proportional to its frequency i.e., $m = \dfrac{h}{c^2} \upsilon$), some of the most incredible mysteries of the quantum realm (a jitter in the amorphous haze of the subatomic world) got far less attention than Schrödinger's famous cat. Virtual particle-antiparticle pairs of energy ΔE were continually created out of the empty space consistent with the Heisenberg's uncertainty principle of quantum mechanics (which implied: $\Delta E \times \Delta t \geq \dfrac{\hbar}{2}$, where: Δt stood for time during which virtual particle-antiparticle pairs appeared together, moved apart, then came together and annihilated each other giving energy back to the space without violating the law of energy conservation − which stated that energy can neither be created nor destroyed; rather, it can only be transformed from one form to another).

Spontaneous births and deaths of roiling frenzy of particles so called virtual matter – antimatter pairs momentarily occurred everywhere, all the time − violated the Energy-momentum relationship: $E = \sqrt{p^2 c^2 + m_0^2 c^4}$ − was the conclusion that mass and energy were interconvertible; they were two different forms of the same thing. However, spontaneous births

and deaths of so called virtual particles could have produced some remarkable problem, because an infinite number of virtual particle-antiparticle pairs of energy ($\Delta E \neq \Delta pc$) were spontaneously created out of the empty space, therefore, by Einstein's famous equation $E = mc^2$, infinite number of virtual particle antiparticle pairs bared an infinite amount of mass and according to general relativity, the infinite amount of mass could have curved up the universe to infinitely small size. But which obviously had not happened. The word **virtual particles** literally meant that these particles were not observed directly, but their indirect effects were measured to a remarkable degree of accuracy. Their properties and consequences were well established and well understood consequences of quantum mechanics. Everything was quantum. Subatomic particle behavior was governed by quantum mechanics, which produced different rules of physics for the very small entities. Without quantum mechanics, atoms would have not existed. The electrons, as they whizz around the nucleus, would have lost energy and collapsed into the center, destroying the atom. However, quantum mechanics prevented this from happening. The rest mass energy of each particle in the universe was given by: $m_0c^2 = k_B T_p$, where: T_p implied the threshold temperature below which that particle was effectively removed from the universe.

All quarks possessed baryon number $= \dfrac{1}{3}$ and all antiquarks possessed baryon number $= -\dfrac{1}{3}$. All the known subatomic particles in the universe belonged to one of two groups, Fermions or bosons. **Fermions** were particles with integer spin $\dfrac{1}{2}$ and they constituted up ordinary matter. Their ground state energies were negative. **Bosons** were particles (whose ground state energies were positive) with integer spin 0, 1, 2 and they acted as the force carriers between fermions (For example: The electromagnetic force of attraction between electron and a proton was pictured as being caused by the exchange of large numbers of virtual massless bosons of spin 1, called photons). The equation $S = \dfrac{k_B c^3 A}{4\hbar G}$ implied that information about what fell into a black hole was stored like that on a record, and played back as the black hole evaporated. 6.022×10^{23} was the number of atoms, molecules or particles found in exactly one mole of substance.

The inverse of H was Hubble time and H was = Fractional rate of change of the scale factor of the universe. Since the gigantic universe was expanding adiabatically then it satisfied the first law of thermodynamics:

$$0 = dQ = dU + PdV$$

where: Q denoted the total heat which was assumed to be constant, U the internal energy of the matter and radiation in the universe, P the pressure and V the volume of the universe. The change of energy of stationary black holes was related to change of area, angular momentum, and electric charge by the equation:

$$dE = \frac{\kappa}{8\pi} dA + \Omega dJ + \phi dQ$$

where: E denoted the energy, κ the surface gravity, A the horizon area (which was a non-decreasing function of time: $\frac{dA}{dt} \geq 0$), Ω the angular velocity, J the angular momentum, ϕ the electrostatic potential and Q the electric charge. Fossil Fuels consisted largely of hydrocarbons, derived from decay of organic materials under geological conditions of high pressure and temperature. The rest mass energy of an electron was $m_e c^2 = 0.511$ MeV and the rest mass energy of a proton was $m_P c^2 = 938.3$ MeV. And 1 eV was $= 1.6 \times 10^{-19}$ J. The flux received at Earth from a star of luminosity L at a distance r was given by an inverse square law:

$$Flux = \frac{L}{4\pi r^2}$$

The decay time of free neutron was 940 s, about a quarter of an hour. Since protons out mass electrons by a factor of 1836 to 1, the mass density of electrons was only a small perturbation to the mass density of protons and neutrons. Photons ionized an atom by kicking an electron out of
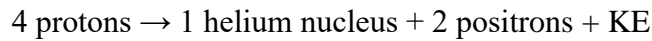
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its orbit, this process was known as **photoionization**. And higher energy photons broke an atomic nucleus apart; this process was known as **photodissociation.** Light from a distant star which just grazed the Sun's surface deflected through an angle: $\alpha = \dfrac{4GM}{c^2R}$, where M and R denoted the mass and radius of the sun. The ionization energy of hydrogen atom was: Q = 13.6 eV. A photon with an energy $h\upsilon > Q$ was capable of photoionizing a hydrogen atom:

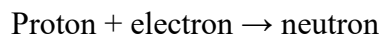<p align="center">Hydrogen atom + photon → proton + electron</p>

This reaction rushed in the opposite direction, as well; a proton and an electron underwent radiative recombination, forming a bound hydrogen atom while a photon carried away the excess energy: proton + electron → Hydrogen atom + photon. An atomic nucleus of radius = 1.25×10^{-15} m $\times \sqrt[3]{\text{Atomic mass number}}$ contained Z protons and N neutrons, where Z was ≥ 1 and N was ≥ 0. Protons and neutrons were collectively called nucleons. The total number of nucleons within an atomic nucleus was termed the mass number, and was given by the formula: A = Z + N. The proton number Z of a nucleus determined the atomic element to which that nucleus belonged. When a neutron and a proton were bound together to form a deuterium nucleus, energy of 2.22 MeV was released: proton = neutron ↔ deuterium + 2.22 MeV. The radiant intensity varied with wavelength and was a maximum for a particular wavelength "λ_{max}" for a given star. The wavelength corresponded to the value of λ_{max} decided the color of the star and one could calculate effective surface temperature of the star "T_S" using **Wien's displacement law**: $\lambda_{max}T_S = 2.897 \times 10^{-3}$mK. For example: effective surface temperature of the sun was 5800K, this corresponded to $\lambda_{max} \approx 5500$ Å. Hence, the sun appeared yellow in color. According to virial theorem:

$$\text{Thermal energy was} = -\frac{1}{2} \text{ gravitational potential energy}$$

Since gravitational potential energy was negative for any bounded system. Thermal energy was always positive. Fusion reactions took place only at very high temperature of the order of 10^7 to 10^9K. Hence, these reactions were termed thermonuclear reactions. A star was able to control thermonuclear reaction in its core because of its strong self gravity. The nuclear fusion reaction occurring inside a star was as follows:

$$4 \text{ protons} \rightarrow 1 \text{ helium nucleus} + 2 \text{ positrons} + \text{KE}$$

where: KE denoted the total energy was released in the form of kinetic energy of different particles. White dwarfs were hot stars of lower luminosity. These stars had lower radius than compared to the sun. There was a mass limit to neutron stars. It was approximately about 4 solar masses. Beyond this limit the degenerate neutron pressure was not sufficient to overcome the gravitational contraction and the star collapsed. There was no mass limit to the mass of a black hole. As there was no agency which can prevent the collapse of the dark star, the entire mass of a black hole shrinked to a point of infinite density. Atom was composed of a tiny nucleus in which its positive charge and nearly all its mass were concentrated, with the electrons some distance away. Therefore most of the space in an atom was empty. When an electron was absorbed by the atomic nucleus, a nuclear proton became a neutron:

$$\text{Proton} + \text{electron} \rightarrow \text{neutron}$$

Thus in this process Z was reduced to $(Z - 1)$ and N was increased to $(N + 1)$. A reaction in which energy was absorbed was termed endoergic or endothermic reaction. And a reaction in which energy was released was termed exoergic or exothermic reaction.

The photoelectric effect was explained in terms of the energy conservation. The energy of a single photon was $E = h\upsilon = W + \frac{1}{2} mv_{max}^2$, where W denoted the work function required to remove an electron from the metal surface, and v_{max} the maximal velocity of the emitted electron. A Wave and particle aspect of radiation was:

Wave nature	Particle nature
Polarization	Photoelectric effect
Interference	Compton scattering
Diffraction	Blackbody radiation

The wave function ψ was complex, but the product ψψ was always real and a positive quantity. The number of isotopes varied from element to element and was larger for heavier elements – i.e. those with a greater number of nucleons. The heaviest naturally occurring element was uranium, which possessed nineteen isotopes, all of which owned 92 protons. The most common of these was U^{238}, which contained 146 neutrons, while the isotope involved in nuclear fission was U^{235} with 143 neutrons. When a neutron was added to a heavy nucleus, such as U^{235}, it underwent fission into smaller fragments. More neutrons were released in this process, which led to a chain reaction triggering the fission of other nuclei.

Nuclides with the same mass number were termed isobars,

Nuclides with the same atomic number were termed isotopes,

Nuclides with the same neutron number were termed isotones.

The fourth state of matter was **plasma** − a state made of positive and negative electric charges and electromagnetic radiation − which was abundant in the Universe because it was present in the stars. The behavior of photons in matter was very different from that of charged particles. Indeed, the photons were subjected to numerous interactions with atomic electrons − the photoelectric effect, Compton scattering (including Thomson and Rayleigh collisions) and pair

production. An electron-positron pair was created by a high energy photon in the Coulomb field of a nucleus: *gamma photon + nucleus → electron-positron pair + nucleus*. The electromagnetic interaction was considered as a unification of the electrostatic and magnetic forces and the electrostatic force was ruled by Coulomb's law: $F = K \dfrac{q_1 q_2}{r^2}$, where q_1 and q_2 denoted the point-like particle electric charges, r the distance between them, and K was a proportionality constant $\approx 8.988 \times 10^9 \, \text{Nm}^2\text{C}^{-2}$. The electrostatic force attracted or repelled particles, depending on the relative sign of the charges. The Planck mass $\sqrt{\dfrac{\hbar c}{G}}$ which was a huge mass compared to the most known massive particles and the Planck length was $\approx 10^{20}$ smaller than the proton size. Particles with masses in the range 0.1–3GeV/c^2 and with lifetimes ranging from 10^{-6} to 10^{-12} s decayed via the weak interaction. The density of the universe was expressed as the sum of different density terms:

- Visible baryonic matter
- Nonvisible baryonic matter
- Nonbaryonic dark matter
- Neutrinos
- Dark energy

Nuclear forces were stronger by a factor of 137 from the electromagnetic force and were stronger by a factor of 10^{40} from gravitational forces − did not depend on the electric charge and had an interaction range of about 10^{-15} m. The nuclear volume was proportional to the number of nucleons: $R^3 \, \alpha \, A$. The radon was a noble and radioactive gas formed by the decay of radium in the uranium decay chain. Alpha particles were helium nuclei which were very stable and with a binding energy $\approx$ 28:3MeV. Magnetic moment of an electron was one Bohr magneton: $\mu_B = \dfrac{e\hbar}{2m_e}$ while that of a proton was one nuclear magneton: $\mu_N = \dfrac{e\hbar}{2m_p}$. The weight of 1 atom of ^{12}C was 12 amu and 1 amu was $\approx 1.660538 \times 10^{-27}$ kg.

The Compton wavelength $\dfrac{h}{m_0 c}$ of a particle characterized the length scale at which the wave property of a given particle started to show up. In an interaction that is characterized by a length scale larger than the Compton wavelength, particle behaved classically (i.e., no observation of wave nature). For interactions that occur at a length scale comparable than the Compton wavelength, the wave nature of the particle began to take over from classical physics. The black hole of mass M emitted thermal Hawking radiation at the rate $\dfrac{Mc^2}{3t_{ev}}$ through its evaporation time.

As the black hole lost mass, the temperature of the black hole (which was $=\dfrac{\hbar c^3}{8\pi GMk_B}$) raised and its rate of emission of particle increased, so it lost energy more and more quickly at a rate proportional to $\dfrac{1}{M^2}$. The black hole ought to emit particles and radiation as if it were a hot body with a temperature that depended only on the black hole's mass: the higher the mass, the lower the temperature. The total entropy of the universe S_{uni}, was continually increasing with time and entropic energy of the universe was never less than or greater than $T \times S_{uni}$ but $= T \times S_{uni}$. The universe obeyed the relation:

$$dS_{uni} \geq 0$$

Because h was very small, the frequency of the photon $\upsilon = \dfrac{E}{h}$ was always greater than its energy. And the only thing that quantum mechanics was going for it, in fact, is that it was unquestionably correct. Since the Planck's constant was very small, quantum mechanics was for little things and quantum mechanical effects were not noticeable for macroscopic objects. In expanding space, recession velocity kept increasing with distance. Beyond a certain distance, known as the Hubble distance $\dfrac{c}{H}$, it exceeded the velocity greater than the speed of light in vacuum. However, this was not a violation of relativity, because recession velocity was caused not by motion through space but by the expansion of space.

The effective temperature experienced by a uniformly accelerating observer in a vacuum field was given by: $T_U = \dfrac{\hbar a}{2\pi c k_B}$, where a denoted the acceleration of the observer, k_B the Boltzmann constant, $\hbar$ the reduced Planck constant, and c the speed of light in vacuum. The entire electromagnetic spectrum — from radio waves to gamma rays, most of the light in the universe — resembled nothing but transverse waves of energy $E = \dfrac{hc}{\lambda}$, which in turn were vibrating Maxwell force fields differing only in their wavelength $\lambda = \dfrac{h}{p}$. The Coulombic repulsive force between two protons inside the nucleus was 10^{36} times the gravitational force between them. The nuclear attractive force between two neutrons was 10^{38} times the gravitational force between them. The nuclear reaction occurring inside the sun, irrespective of pp or CNO cycle, was as follows: 4 protons → 1 helium nucleus + 2 positrons + E, where E denoted the energy released in the form of radiation. Approximately it was $25 \text{ MeV} \approx 40 \times 10^{-13}\text{J}$. The unification of so called weak nuclear forces with the Maxwell equations was what known as the Electro weak theory. And the electro weak theory and QCD together constituted the so called Standard Model of particle physics, which described everything except gravity. Material, such as gas, dust and other stellar debris that approached the black hole prevented themselves from falling into it by forming a flattened band of spinning matter around the event horizon called the **accretion disk**. And since the spinning matter accelerated to tremendous speeds ($v \approx c$) by the huge gravity of the black hole the heat and powerful X-rays and gamma rays were released into the universe. Because $r = \dfrac{3GM}{c^2}$ the photon spheres existed only in the space surrounding an extremely compact object (a black hole or possibly an "ultracompact" neutron star).

This story of a universe that started off very hot and cooled as it expanded is in agreement with all the observational evidence that we have today. Nevertheless, it leaves an important question unanswered whether the laws of physics had any choice in the creation of the world. And this is a fundamental question. And compared to this question, all other questions seem trivial. Yes, it would have had many choices if it had wanted to set the value of the speed of light much smaller

than its actual value and the values of electron mass, proton mass, and constants determining the magnitudes of electromagnetic interaction, strong interaction, and weak interaction much larger than their actual values. However, in order to have sun-like stars in the universe which can sustain life; it seemed that it had only limited choices.

Big Bounce Model:

The universe is expanding with time − the universe continues to decrease in density and fall in temperature, hence the typical energy of each particle is decreased in proportion to the fall in temperature (since the average energy – or speed – of the particles is simply a measure of the temperature of the universe) − and at a certain point of expansion, the density of the universe will be greater than critical density. The universe will lack the repulsive effect of dark energy, then gravity eventually cease the expansion and it start to contract the universe until all the matter in the universe collapses to a one-dimensional point which contains a huge mass in an infinitely small space, where density and gravity become infinite and space-time curves infinitely, and where the laws of science as we know them cease to operate. At first, the rate of contraction will be slow, but the pace gradually pick up − the universe shrink more or less evenly on a gross scale. The temperature will begin to increase exponentially – stars explode and vaporize, and eventually atoms and even nuclei tear apart in a reverse performance of the early stages after the Big Bang

Matter will be under extreme conditions:

Matter + heat + pressure → quark–gluon plasma + photons + other elementary particles

As the universe become compact into a very small volume, slight irregularities become ever more magnified and, in the final stages, the collapse turn to be wildly chaotic, and gravity and the warping of space-time vary immensely depending on the direction the singularity is

approached by an in-falling matter. Very close to the singularity, the common laws of physics governing our daily environment are abandoned and the rules of quantum mechanics come into play − the universe continues to contract not to the point of singularity, but to a point (finite critical size, well above the Planck length $\sqrt{\dfrac{\hbar G}{c^3}} = 1.616255(18) \times 10^{-35}$ m) before that where the quantum effects of gravity become so strongly repulsive that the universe rebounds back out, forming a new branch. This implies that the Universe operates sort of like a balloon, where it expands from a single point, grows and grows until it reaches some maximum distance, and then contracts back to the original point, starting the whole process over again.

The Big Bounce is a hypothetical cosmological model for the origin of the present universe. It was originally suggested as a phase of the cyclic model or oscillatory universe interpretation of the Big Bang, where the first cosmological event was the result of the collapse of a previous universe − so in this way the universe would last forever, but would pass through phases of expansion (Big Bang) and contraction (Big Crunch). When it comes to models of the universe, the Big Bang theory is almost accepted as a fact. However, it's still uncertain, and some believe that the universe didn't kick-started with a bang, but a bounce.

Source of Information:

- https://www.wikipedia.org/

"Science is not only compatible with spirituality; it is a profound source of spirituality. When we recognize our place in an immensity of light-years and in the passage of ages, when we grasp the intricacy, beauty, and subtlety of life, then that soaring feeling, that sense of elation and humility combined, is surely spiritual. So are our emotions in the presence of great art or music or literature, or acts of exemplary selfless courage such as those of Mohandas Gandhi or Martin Luther King, Jr. The notion that science and spirituality are somehow mutually exclusive does a disservice to both."

— Carl Sagan